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Human Performance and Resources Group (HUM)

THE TECHNICAL COOPERATION PROGRAM

SUBCOMMITTEE ON NON-ATOMIC MILITARY RESEARCH AND DEVELOPMENT

TECHNICAL PANEL HUM-TP9
HUMAN FACTORS INTEGRATION FOR NAVAL SYSTEMS

WORKSHOP SUMMARY AND PROCEEDINGS

"THE INSERTION OF HUMAN FACTORS INTO THE ACQUISITION PROCESS FOR NAVAL SYSTEMS"

TTCP/HUM/00/011

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TTCP HUM TP9 Workshop
5-6 June 2000
DCIEM, Toronto, Canada

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PREFACE

Technical Panel 9 of sub-group HUM is responsible for conducting collaborative research aimed at integrating Human Factors into the design and execution of safe, manpower efficient and cost-effective systems for future navy warships, as well as updates to existing vessels. This responsibility is met through joint specification and development of HFI tools and methods and collaborative efforts within three Key Collaborative Areas (KCAs):

KCA 1: addresses the impact of new technology on human systems integration issues. Current efforts focus on evaluating the implications of new human: computer interface technology for naval systems, including advanced display technology (e.g., 2D vs. 3D, CRT Vs LCD), improved operator alerting and attention management systems, and software agent technology.

KCA 2: addresses the inclusion of human factors integration (HFI) in the ship design and development process and has resulted in the adoption of a generic model for HFI. Current activities include the identification of HFI tools and models, their point of application in the integration process, and development of an HFI Capability Maturity Model.

KCA 3: covers the Panel's current main task 'Tools for optimizing naval platform manning and manpower requirements,' approved by HUM in 1999. Following the transfer of available manning models among the nations, the UK completed a comparative evaluation of available models using a common data set from a RN ship. This will lead to the requirements for improved manning and complementing tools.

In support of these KCAs, workshops have been held on the following topics:

- 'Human factors in requirements definition and criteria for acceptance,' May 1996 (published as TTCP/SGU/96/11).
- 'Lean/Austere manning', May 1997, (published as TTCP/HUM/97/008).
- 'Design and evaluation of principal operating areas in warships,' May 1998 (key points from the workshop are listed at Annex A).
- 'Optimized manning,' May 1999, (classification of the briefings is at Annex B).

Major conclusions of the 1999 workshop were that manning is a major driver of through-life costs and that lean manning is the current major challenge, but the acquisition process and new command system technologies will facilitate lean manning and will require focussed effort in the future. With that background in mind, a workshop on 'The insertion of human factors into the acquisition process for naval systems' was held 5 – 6 June 2000 addressing the following topics:

1. Human factors/ human systems integration (HFI/ HSI) in policy and practice.
2. HFI/ HSI capability maturity models and assessment techniques.
3. Tools and technologies to support HSI/ HFI in the acquisition process.

Workshop Topic 1

Human Factors/Human Systems Integration (HFI/HSI) in Policy and Practice

Australian Perspective

Presenter,
Maritime Platforms Division, Defence Science & Technology Organisation (DSTO), AS

Human Factors/Human Systems Integration is an important component of the capability development and acquisition process for the Royal Australian Navy (RAN). Policy for HSI/HFI is in general high level guidance. The development and acquisition of capability for the Royal Australian Navy has followed a well documented but in some ways stovepiped process, with separate organizations responsible for capability development, acquisition and support. Some projects have incorporated HSI/HFI successfully, but success depends on how early it is included in the capability development process. Successes include the Wedgetail AEW aircraft acquisition where HF considerations were included from the beginning and a large effort was devoted to it. Emphasis was placed on crew workload and system effectiveness and there was an evaluation of tendered solutions for the human machine interface (HMI).

The situation described by the examples is evolving:

- The 'new' navy organization is based on Force Element Groups (FEG), with each FEG commander responsible for delivering total capability within the FEG.
- There is growing acceptance within each FEG of the critical importance of getting the HSI/HFI equation correct.
- The creation of the Navy Systems Command, with specific reference to HFI.
- There is increased R&D effort within DSTO in HSI/HFI.

All new acquisition projects are to take into account through-life costs, including personnel costs and HSI/ HFI is an essential element in the new capability management system. In addition, the RAN are developing standards for HSI/HFI for future acquisition projects.

Workshop Topic 1

Human Factors/Human Systems Integration (HFI/HSI) in Policy and Practice

Canadian Perspective

Presenter,
Defence R&D Canada, DSTHP 3, Ottawa, Ontario,

Presenter,
Options Inc. Consultants Waterloo, Ontario, and

Presenter,
Defence & Civil Institute of Environmental Medicine Toronto Ontario, CA

In the Canadian Department of National Defence (DND), lessons learned from previous projects coupled with growing concern about life-cycle costs have lead to increased emphasis on HSI. This emphasis has been formalized by the inclusion of HSI issues in the new "Guidelines for the Preparation of a Statement of Operational Requirements", the key initial document for Material Acquisition and Support (MA&S) this year. In response to requests from acquisition projects, and to support the desk officers developing Statements of Operational Requirements (SORs), Defence Research and Development Canada (DRDC) has recently put together the elements of a centralized HSI Programme and Support Team. The mission of the programme is "The pursuit of optimal health, safety, human factors engineering and human performance through the application of HSI principles in Military systems involving the human element."

DRDC has taken on this HSI Program approach and role through requests from DND acquisition project personnel who have consistently indicated that a centralised programme of this nature is required. This DRDB HSI initiative has not been designed with an attempt to combine or alter the current responsibilities of the different disciplines or HSI domains. Instead, the intent of the present approach is to better integrate:

- these disciplines into the mainstream of the MA&S process,
- common aspects of each domain's analysis, and
- HSI related R&D activities.

This programme is being co-ordinated by DRDC but requires the input and participation of a number of stakeholders. The programme has several constraints:

- ***Minimal Resources*** are available to support the programme.
- Life Cycle Cost Impact of HSI, or any lack thereof is a major concern to DND.
- The current business culture includes SMART, M&S / SBA, RMA & RBA.
- HSI responsibilities in DND are dispersed and efforts must be linked.
- Lack of much depth in the HSI Skill Base in CA.

The initiative has three primary components: 1) people, 2) process, and 3) tools.

'People' refers to HSI resources throughout DND, including representatives from directorates responsible for each HSI Domain and co-ordinators such as those responsible for advising on HFE and logistics support efforts in acquisition projects. In the absence of resources to staff an 'HSI Directorate' the approach being taken is to create a 'virtual team' of HSI specialists through electronic media links. Potential members of the 'virtual team' have been interviewed. General reactions are that the HSI specialists support the programme but they need hard products to focus on. It is anticipated that the team will support acquisition projects in one of three ways: either the project staffs and conducts its own analysis, or the project obtains its own contractors, or the project asks the 'virtual team' for support. A DND HSI Steering Board is to be formed to advise the programme. In addition a 'UK style' directory of HSI points of contact in industry will be developed by voluntary submission of information, and advisors will be sought from the HSI Industrial Base once the programme is established.

'Process' refers to a recommended analysis process for acquisition and support projects to ensure that HSI is properly integrated into future materiel systems. A 'top level' HSI Process has been drafted and will be developed further. The requirements established for the process were that it be simple, sequenced, provide links and show interactions between the HSI domains, accord with the Defence Management System, map onto the larger DND acquisition process and the Life Cycle Material Management system, and accommodate both developmental and Commercial Off-the Shelf (COTS) acquisition projects.

'Tools' refers to modelling, simulation and analysis tools used in the HSI process, many of which are already in use throughout DND, such as SAFEWORK™, HEART, SOLE IPME, HFE Guide, HFE ICADD, etc. (see http://www.crad.dnd.ca/hsi/tools_e.html). These tools will be further developed to support analysis of HSI issues, and demonstrations of design concepts embodying HSI principles. The programme plan anticipates that the tools will also be used to develop libraries of analyses and simulations. To facilitate communication it is planned to introduce an electronic newsletter to which any HSI specialist can contribute.

The aim is for all domains to be involved earlier in the acquisition cycle and for all to be kept current as project assumptions change throughout the cycle. To further facilitate this integration, DRDB has established an HSI Web Site to provide information and visibility to both project personnel and the HSI community (see http://www.crad.dnd.ca/hsi-toc_e.html). The Web site will identify personnel or directorates who can support acquisition projects, for example those currently responsible for Training, HFE personnel will be indicated as the HFE experts, etc. The Web site will also be linked to the electronic Acquisition Officer's Desktop later this year.

In conclusion, it is hoped that such a centralized HSI approach with a virtual HSI Support team in DND can ensure an optimal consideration of human factors as well as an optimal integration and re-use of models, simulations and analyses between the various HSI domains.

Workshop Topic 1

Human Factors/Human Systems Integration (HFI/HSI) in Policy and Practice

UK Perspective

This presentation was given by a representative of the Directorate of Naval Manning, UK, with the assistance of Defence Evaluation and Research Agency (DERA) & Defence Procurement Agency (DPA) Sea Technology Group, UK; DERA Centre for Human Sciences, UK, DERA & DPA Future Business Group, UK.

The HFI programme in the UK has six domains: manpower; personnel; training; human factors engineering; health hazards assessment, and system safety. Survivability is under consideration as a domain but it is considered as either something done within the integration of the domains or, in the opinion of the Sea Technology Group, it is already addressed. Following from the UK's recent strategic defence reviews (SDR) the move to acquiring military capabilities, rather than equipment, makes consideration of human issues from the earliest stages increasingly critical. The Royal Navy has an ambitious equipment acquisition programme involving ever more challenging budgets, diversifying roles and a potentially volatile human resource base. Capability Management, post-SDR Operational Doctrine and Tasks, 'Smart' (= better, faster, cheaper) procurement, and the discipline of HFI, informed by quality research and comprehensive Operational Analysis and Costing (OAC) methodologies should combine to ensure that the role of the human is properly considered in these new acquisition programmes.

HFI has been established as a systematic process within the Procurement Strategy (see Annex C). Mechanisms are in place to provide a focus for HFI within acquisition projects. Guidance has been developed for HFI in capability management and the management of HFI throughout acquisition. Current documents include:

- HFI and Capability Management,
- Introduction to HFI,
- Practical Guide to HFI,
- Introduction to Target Audience Description (TAD), and
- Practical Guide to Target Audience Descriptions.

(The Chief of Defence Procurement Instruction and the Defence Procurement Management Guide have been overtaken and the HSI community is working to bring HFI Procurement Management into one document). The guidance is available through a newly developed HFI web site that is integrated within the MOD’s Acquisition Management System (AMS) web site. It can be characterized as being more 'what' to do than 'how' to do it.

With the introduction of Smart procurement as an outcome of the 1997/98 Strategic Defence Review, the opportunity was taken to reassess HFI processes and learn from the experience of the last nine years. A number of key lessons have been learnt. First, there was an implicit assumption that all equipment projects would have their own specialist ‘in-house’ HFI practitioner. With 800 projects and only a very small number of specialists this was a major barrier to the comprehensive application of HFI. Related to this, it was concluded that the HFI instructions and guidance available had not reached maturity before the process was brought in.

Second, it was apparent that if HFI was viewed as being “owned” by the HF community difficulties arose in gaining acceptance by projects. Therefore the responsibility for managing and developing project-specific HFI strategies and plans has been passed to project staff. Projects are now required to nominate an HFI focus within the core team, although this will not normally be a HF practitioner. In naval projects they are naval architects, marine engineers, etc., with no HF training. These foci are responsible for co-ordinating HFI activities across the programme, and for ensuring that key stakeholders, including end users and industry, are involved and consulted throughout the procurement process. Integrated Project Teams (IPTs) have the responsibility for managing HFI but they are encouraged to seek HFI advice. Experience is that this may increase rather than decrease the role and status of practitioners.

Third, because of the scope of the effort involved (there are currently 140 IPTs) non-specialist staff may carry out some HFI activities, in fact some activities are being performed by default. To support staff involved in these activities HFI techniques have been developed. This has required the redefinition of the Target Audience for many HFI products and a series of workshops has been held to assist in the validation of this new approach. In the workshops mock-working groups/IPTs employed the emerging HFI guidance in ‘hypothetical’ projects.

The Sea Technology Group is working to supplement the current guidance documents with a Naval Equipment Human Factors Guide intended for both MOD and industry users. They are also studying training for IPT personnel including:

- HFI in project definition, design and development,
- the link with Smart Procurement,
- the impact of user capabilities and performance under operational conditions,
- overview of HF methods, tools and techniques,
- understanding the role of HF in system engineering process, and
- identifying risks as early as possible.

Guidance on producing the TAD is also being looked at. They currently have multi-page instructions on how to do it. The process is easy to say but more difficult to do because crewing concepts evolve along with the hardware and software concepts and training needs analyses. Finally, the sea Technology Group is the sponsor of the Complement Regimes Evaluated for

Warships (CREW2) manpower modelling software programme. It is still an evaluation tool. Three copies have been delivered.

Other common themes identified from experience are:

- There must be early commitment from both the user and industry.
- Systems and software integration tasks should not be underestimated.
- Project staff should be wary of 'COTS' solutions in military scenarios.
- Differences between Equipment and Operational capability foci are significant.
- Cost criteria produce different results than cost-benefit criteria.
- IPTs should distinguish between procurement costs and life-cycle costs.
- Task analysis data from previous systems may not be relevant to new organizations.
- Performance measures are a concern - they can be difficult to identify.
- HSI practitioners must establish clear requirements and goals.
- Mock-ups and test rigs have great value to HFI.
- There should be a training needs analysis for HFI.

The HFI programme is starting to have an effect. The Royal Navy is aiming to ensure that the need to meet and sustain the appropriate level of human effort is properly understood and included in programme planning. The end user is becoming far more involved in procurement at an early stage. The Directorate of Naval Manpower's Strategic Manpower Review is about to commence in earnest. Considerable effort is being applied to design a framework for capturing Manpower and Human Factors 'Requirements' in a rigorous, irrefutable and assessable manner within the framework of the UK's HFI process.

Workshop Topic 1

Human Factors/Human Systems Integration (HFI/HSI) in Policy and Practice

US Perspective

Presenter,
Director, Optimal Manning Program,
Program Executive Office Surface Strike, PEO (S)-M,
Arlington, Virginia, US

DD-21 land-attack destroyer (named the Zumwalt class on 4th of July) and CG-21 are part of the SC-21 family combatants that the US Navy is planning for the 21st century. Earlier this year the Program Executive Office for DD 21 and was re-organized and re-designated as the Program Executive Office for Surface Strike—PEO (S). TP-9 member he was transferred from his position as Head, DD 21 Manning/ Human Systems Integration Department to Director, Optimal Manning Program within PEO (S). Jennifer McKneely is taking over responsibility as functional area leader for manning and HSI within the DD-21 programme.

DD-21 is the first major programme in the US Navy to incorporate HFI from the beginning. Goals for the project include reducing operation and support costs, and manning levels, by 70% of the DDG 51 class while maintaining 90% availability. The basic problem in achieving such goals is the view of the system that is held by the agencies involved in procurement - that it is just hardware and software. The human component is ignored because it is paid for by different agencies.

In such programmes, human factors engineering (HFE) is the most important domain because if the system is not designed properly the HSI specialists cannot be effective in the Manpower, Personnel and Training (MPT) domains. The influence of HFE is apparent in the basic approach to zero-based manning. Figure 1 shows how a linear increase in Cost with the number of crew, and a non-linear decrease in automation with the number of crew combine to form a U-shaped curve of total costs to meet specified missions. In the early stages of the SC-21 programme effort was put into developing tools and processes for each of the HSI domains, with a strong emphasis on the HFE domain. As the programme matures there is an increasing challenge to translate high level concepts into policy and practices that work.

To achieve Optimized Manning requires fundamental changes to the policy and culture of the Navy in the way that ships are acquired, engineered, operated and manned. For example, the typical manpower 'pyramid' with a large base of the lowest ranks and diminishing numbers of higher ranks must change to a manpower 'pentagon' with more people at the intermediate rank levels. This raises the problem of career progression up to and including the intermediate ranks.

Statutes and doctrine will also have to change. For example, the resource sponsor only ever buys 90% of manning; how do you buy 90% of 95 people? It the navy does not make complementary changes in the areas of personnel recruitment, selection, training, and career streaming, to meet the new optimized manning design, it will not work. The need for advanced preparation is so serious that the programme has requested personnel agencies to inform them now if they are not going to allow such changes. In April 2001 the US Navy will select the winning proposal for developing the DD-21. This leaves them ten years before taking delivery of the ship, but only four to five years before they must start on the crewing issues. So they must prepare now for the future.

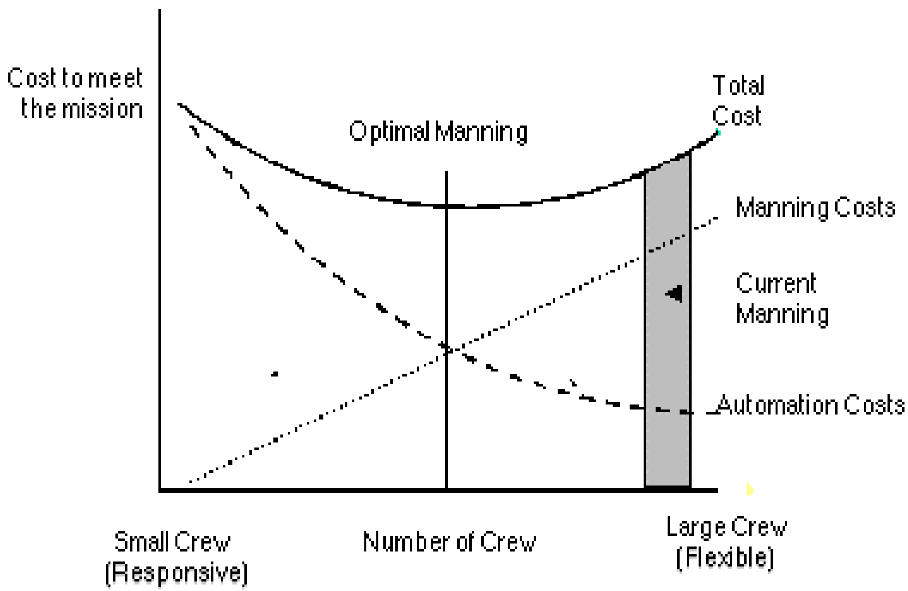

Figure 1: Optimized manning

In FY99-00 progress in implementing and institutionalising HFI/HSI processes for US Navy surface combatants focussed on supporting the MPT domains. A noteworthy development in this connection has been the formation of a Policy Clearinghouse (PCH) to provide a mechanism for identifying MPT issues that are tied to Navy policy, statute, procedure, and culture. Inputs to the PCH will be solicited from interested parties using a web-based, global network for issue identification and collection. Work has been initiated on a network-centric project management tool to discuss, collect, identify, display, asses risk, resolve and disseminate MPT policy, statute, practice and cultural issues. The Policy Working Group, one of three integrated product teams supporting the DD 21 Manning/HSI organization, will manage the PCH, ensuring that MPT issues are not only collected, but also assessed and resolved.

It is intended that the PCH facilitate global, cradle-to-the-grave collaboration between the Fleet, industry, and others involved in MPT issues focussing on critical and time-sensitive issues and improving the Navy's reaction time to them.

In closing, he noted that the ultimate crew size for DD 21 will be optimized, by definition, because it reflects what the US Navy can afford (both personnel and technology wise) before the ship deploys.

Workshop Topic 1

Human Factors/Human Systems Integration (HFI/HSI) in Policy and Practice

UK/US Technology for Optimized Manning (TOM) Initiative

Presenter,
Naval Undersea Warfare Center,
Newport, Rhode Island, US

The bilateral (US/UK) initiative known as Technology for Optimized Manning (TOM) is focusing on the application of existing and emerging technology to support optimized manning for naval platforms with service entry dates between 2010-2020 (i. e., post-FSC, DD 21). The initiative, which was run initially under the aegis of a bilateral Master Information Exchange Memorandum, was established following discussions between RADM Phillips from the RN and RADM Gaffney from the USN in March 1999.

A joint workshop was held in February 2000 and produced four major outcomes. These outcomes included consensus on a definition of optimized manning and agreement on the issues to be addressed in subsequent UK/US workshops. In addition the workshop pulled together US/UK technologies that are current, ongoing, or may be available by 2015, and established a schedule and goals for future joint meetings. The definition for optimized manning adopted by the initiative was as follows: "The manning is to be sufficient to meet the manpower effort required to successfully fulfill the tasks of the unit throughout its planned lifecycle at minimum cost and acceptable risk to the service". "Minimum cost to service" includes "costs related to infrastructure (e.g., training, maintenance, recruitment, retention)."

Major components of an optimally manned ship were agreed on as:

- HSI and human centred design,
- top-down function allocation and crew modelling,
- advanced decision support and information management,
- simulation based: training / recruitment screening' skill assessment,
- high performance distributed computing,
- condition-based monitoring and control,
- collaborative planning and interoperability issues,
- net-centric warfare/ force data fusion/ bandwidth issues, and
- new materials, coatings.

Multi-cultural issues in Combined Ops were also mentioned as an area for collaboration.

Work programmes in each nation that support advances in the above-listed areas were reviewed, together with ship building programmes that provide potential routes for transferring the technology. Building programmes include the US SC-21 and the UK's Type 45, which aims for a 37% reduction in annual running costs (Janes Defence Weekly, 5 July 2000). Areas of potential technology application include:

- future battlespace and technology,
- personnel and future systems,
- human system integration and technology, and
- whole ship integration.

Because this approach to future ship design and development is driven by manning issues and advanced technology, end products are expected to provide more freedom to pursue innovative solutions of long-term benefit to the Navy and Marine Corps. Summaries and points of contact will be provided for other US Navy Manning Optimization and Human Factors Integration programmes, several of which involve bilateral UK/US collaboration.

Plans were agreed upon for a bilateral workshop in June 2000 to:

- identify relevant national programmes that may produce technologies that will have an impact on manning levels,
- conduct a gap analysis for each national programme and for the joint programme, and
- propose collaboration in areas to address perceived shortfalls, develop US/UK teams to address individual issues, outline milestones, deliverables, funding.

From the work to date it appears that there are S&T challenges in the areas of:

- virtual presence, tele-presence, tele-operation,
- distributed collaboration & decision support, and
- intelligent network agents (automated information search).

She has been exploring the possibility of expanding the initiative and linking it to ongoing advanced computer technology programmes in France, Germany, Japan and The Netherlands. She has talked to programme managers in the above nations about the work of HUM TP-9, many of whom were unaware of TTCP but wanted to be part of it.

Topic 1

Human Factors/Human Systems Integration (HFI/HSI) in Policy and Practice

Workshop Discussion

HSI/ HFI in Policy

The discussions included the scope and domains of HSI/ HFI, the overall approach taken, and standards and specifications for HSI practice. Some in the US Navy want to make 'habitability' the 7th domain of HSI ('soldier survivability' is the 6th domain of MANPRINT). The UK had considered accommodation and habitability to be a domain when the RN had a separate HFI programme, the RN HFIP (MANPRINT MAIL, No. 10, February 1994). One delegate cautioned the workshop on the risk of fragmentation with such a programme. The US had started HSI with two domains but the programme has since split into five (now six) domains.

Discussing the importance of the domains, it was suggested that the MPT domains are the really important ones in the sense of their influence on costs, whereas HFE is the key to making the MPT domains work.

Reviewing the overall programmes that were reported, the UK and CA are dealing with a lot more, high-level structured approach than the US and AS. It was suggested that this is good but the HSI specialists should remember the adage “think globally, act locally” from the environmental movement. The global approach is fine, but the question is how to go about it? The review of lessons learned from the Aegis class may be an example. The review was conducted among operators, with no appropriation, to identify good features and problems. The survey found, for example, an interface that required 5 weeks of training which could be made much simpler and learned in a couple of days. Such problems are the reason that the USN is taking HSI seriously. Also, there has to be change. The armed forces cannot continue to do things the way they have always been done. As an example of acting locally, with the DD-21 project a lot of things just came together, sometimes serendipitously.

CA is taking a high level, structured, approach to support potential users. Having succeeded in placing HSI issues in the new templates for Statements of Requirements (SORs), the HSI community now has to provide information for the staff officers who will be filling in the blanks in those templates. In contrast, the US has the high level structured approach in many of its documents, including Department of Defense instructions. In addition, US NAVSEA have put HFE into a 1998 update to IEEE 1220 (Systems Engineering Standard) and are working with International Standards Organisation for inclusion of HFE guidance in ISO 15288 (System Life Cycle Processes) as well as the International Counsel on Systems Engineering (INCOSE) Systems Engineering Handbook. (For amplifying information refer to http://www.manningaffordability.com/Toolsite/Other/fitwindx.htm).

Such policy, however, means nothing without a cultural change and HSI specialists must take a long-term view of changing the culture. Bost (US) does this by teaching naval architects, engineers, etc. The HSI community also has to tackle all the other areas such as personnel and training, etc. to bring about the necessary changes and to implement HSI from a local standpoint on specific projects. The bureaucracy responsible for MPT and systems acquisition has to change. Tools and methods for implementing the design are being worked on by all.

HSI/ HFI Practice

Issues that were discussed included the application of standards and specifications, the use of joint industry/ government liaison groups, and the Target Audience Description (TAD). The US has the necessary policy documents for HSI, e.g., DoD Instruction 5001/5002 (Defense Acquisition and Defense Acquisition Management Policies and Procedures) series and the US Navy version of those documents, but seldom is much emphasis put in them. The infrastructure is there but if it is not enforced it does not help. The documents provide 'gates' though which projects must pass, but few government managers have held major acquisition projects to requirements at those points. If there are no consequences for ignoring the requirements why should the contractors do it? Another disincentive is that the client agency has to do research or analysis to confirm that there will be performance improvements.

Australian experience includes good and bad examples of specifying the capability of a system. On the Collins class, the risk analysis was wrong. The hull was classified as high risk and the software as low risk. They ended up with 3M lines of software code, all of if bundled, and could not do anything with it. The contractor completed 95% of the work within cost, and 95% of that was working properly, which meant that they only have 40% of the operational functionality that is needed. On the Wedgetail AEW aircraft project, they followed the same approach but put Measures of Performance (MOPs) in place and a risk reduction strategy on the capability, not on the platform.

Some workshop participants, particularly those representing the UK, had mentioned the importance and value of the TAD. During discussion, it was learned that some HSI agencies have never used a TAD (USN); some use it with caution (RN); and some see it as having a lot of potential if written in a way that helps system designers. One user reported experience that the closer you get to the problem the more difficult it becomes. There is need for a guide on how to write one properly[1].

Further, some participants found the Canadian proposal establishing a government/ industry liaison group of interest. The UK has such a group; in the USA the DoD HF Technology Advisory Group (HF TAG) is the nearest to such a group, having representatives from the various industrial associations, such as Aerospace Industry.

[1] The US MANPRINT Bulletin for September/ October 1991 reported that "TADs currently being developed seem to provide little benefit to industry and are imposing great workloads on their developers." No follow-up report of the development of an improved TAD is known.

Workshop Topic 2

HFI/HSI Capability Maturity Models & Assessment Techniques

UK Human Factors Capability Maturity Model

This presentation was given by a representative of the DERA Centre for Human Sciences, UK, and was based upon ongoing work sponsored by the Defence Procurement Agency (DPA) Sea Technology Group, UK.

Human Factors Integration (HFI) sets out to deliver operable (i.e. effective, productive, safe and satisfying) systems. Capability Maturity is a way of determining the extent to which an organization has processes that are defined, managed, measured, controlled and effective (see Proceedings of the Workshop on Human Factors in Requirements Definition and Criteria for Acceptance, TTCP/SGU/96/11, 1996). A Human Factors Integration Capability Maturity Model (HFI CMM) is an objective, structured way of providing assurance of operability and effectiveness and meeting the user requirement, before project resources are committed. The CMM also provides a mechanism for improving HFI processes and a means of mitigating project risk. Studies conducted by DERA conclude that an effective CMM requires the following:

- an established process model,
- an established assessment model,
- a strategy for procurement intervention and support, and
- appropriately trained specialists.

A three-year project undertaken by DERA CHS, Lloyds Register of Shipping and Process Contracting Ltd. is developing an HFI CMM based on these requirements. In the first year a scoping study was conducted and the feasibility and potential benefits of developing a CMM were explored. In the second (current) year, best practices are being collated, and a process model developed and will be trialled in the early stages of procurement. In the final year the HFI CMM will be assessed for use in the later stages of procurement, an 'assessment model' and the skills required by assessors will be established, and the model will be validated.

Nine approaches to HF Process Assessment had been reviewed, including ISO 18529 (UK may use ISO CMM standards as a backup) and models developed by the US General Accounting Office, Federal Aviation Authority, US Air Force, US Office of Naval Research, and DND Canada (the latter having been reported to TP-9 in the Canadian report for 1997). Common themes that emerged from the review were the need to:

- assess whether the user will be considered in system acquisition,
- have a recognized external framework for best practice,
- have clear assessment scales,
- have a plan of action to address findings, and
- integrate the approach with software or system engineering activities.

Common development issues that were identified include:

- inclusion of generic management practices,
- the scope of management, technical, and support practices,
- process vs. culture,
- process vs. expertise & training,
- choice of standards for the framework, and
- links to specific life cycles.

Other issues concern the scope and boundaries with other disciplines. HF/ HFI/ HE/ HSI are centred on acquisition and are considered part of systems engineering activities, whereas the other HSI domains are also related to the employment of manpower & organizational development and overlap with ILS activities and the operation of the system. Development issues to date include:

- the standards quagmire for systems engineering and capability assessment,
- the need for ease of use and value in use,
- the choice between assessment models and guidance documents,
- getting uptake by customers and buy-in from industry, and
- whether the model should define ‘good practice’ or just what people do now.[2]

The proposed HFI CMM has two main technical components (a process model and an assessment scheme) and an implementation strategy for technical validation and operation in support of procurement. The process model is based on established HFI guidance and industrial best practice. Researchers are currently assembling a set of HFI processes that can be integrated into procurement activity, including the phases of concept, development, delivery, operation, and disposal. This provides a sound basis for a HFI CMM tailored to MOD’s new Smart Procurement Initiative. The developers held a two-day meeting where potential users applied the HFI CMM to two projects, TRACE an army programme, and a management programme. They have not had time to do much more, but had planned a second workshop concurrently with the week of theTP-9 meeting.

Comparisons between the UK's proposed HFI CMM with CA and US approaches show several differences. The UK model:

- uses an ISO process /model as reference (ISO 15288, 15407/ 18529, 13407),
- uses a high-level reference model and a detailed assessment model,
- is compatible with ISO 9000/2000 in the assessment model methods,
- emphasizes managing risk rather than achieving a CMM level (SEI CMM level III),
- provides tailoring guidance linked to their acquisition handbook,

[2] The Software Engineering Institute (SEI) CMM would accept 'what people do now' as one of the lower of their 5-level model. In the human factors community the lack of standard procedures and methods would likely place practitioners at level 1 "Ad-hoc, Unpredictable, Chaotic".

- considers HFI boundaries and links between acquisition, MPT and operation,
- addresses management, technical, support and life-cycle issues, and
- anticipates CMM/ SPICE convergence.

Anticipated customer benefits of the HFI/ CMM include assurance for MOD that they will acquire operable systems, reduced risk in contractor selection and possible reduced acquisition costs, and for a framework for shared responsibilities for the Integrated Product Teams. UK developers of the model are now considering the way ahead. Options include information exchange, converging to common models, converging on common models as the Systems Engineering and Computer Engineering model base settles, and using the mode in a multi-national trials environment.

Workshop Topic 2

HFI/HSI Capability Maturity Models & Assessment Techniques

Bridge Cards: A Method for Ensuring the 'Right' Human Factors Questions Are Asked by Senior Management

Presenter,
Section Head, Human Centered Systems Engineering Section,
NAVSEA Dahlgren, Dahlgren, Virginia

Presenter,
VP, BCI Inc.,
Dahlgren, Virginia, US

Texts on implementing change recommend that it should begin at, or be supported by, the highest levels of an organization. Human factors specialists do not work at the top of the acquisition organization and do not make the final decisions. They have to provide support to the engineers as well as influencing the leadership to change. Making alliances and demonstrating corporate advantages to senior project staff are necessary as well as institutionalizing the HSI process.

One example of these principles is the ' Bridge Cards[3] developed in response to a request from the ADM of the Program Executive Office, Theater Surface Combatants (PEO TSC-T) for material to address human factors and human-systems integration (HFI/HSI) issues for existing vessels and new platform acquisitions. Two sets of Bridge Cards were developed collaboratively by Dr. Wallace and Basic Commerce and Industries (BCI) Inc., Dahlgren, Virginia, in support of the ADM's request. The first is titled *Human Factors Top Ten Bridge Card*. It contains two groups of five questions. The first five are general questions:

- How did you (will you) come up with the function allocation between the hardware/ software (equipment/ computer program) aspects of the system and the human operator?
- How are you (will you) ensuring that all of the information is available to the decision-maker without burying him in data?
- Has this concept been presented to a fleet review team and if so what was their reaction?
  - Where will you be setting up your prototype watchstations for human factors testing? Will it be readily accessible to the fleet reviewers and test participants?

[3] In nautical history, a Bridge Card was prepared to assist a ship's Commanding Officer (CO) in establishing the seniority of participating units in a battle group by listing the lineal number (i.e., rank) of each participating units' CO. This concept has been extended over the years to include a variety of lists that enable the CO to 'come up to speed' quickly when confronted with unfamiliar or changing circumstances.

- What are the qualifications of your human factors team? When did they start working on this, and what impact have they had on your designs?
- What additional training will be required for operators and maintainers for this system?

The second set of questions is more specific:

- What analyses have you performed to ensure that these operators can really handle the workload your design will be placing on them?
- What will the operator have to memorize to use this?
- How do you handle operator error? It WILL happen.
- Are these controls standardized with other systems used by the same operators?
- Have you considered operator complaints with previous similar systems in this design, e.g., AEGIS Lessons Learned Program?

The idea behind these questions was to make the contractor realize that these issues are important. The second, more comprehensive Bridge Card, is titled *List of Interoperability, Integration and Human Factors Questions for Acquisition Milestones* (milestones as per US DOD Instruction 5002). It extends the concept of the first bridge card to include questions applicable to each milestone, with human factors folded into other disciplines.

Judging by response, the cards have been quite successful. The bridge cards were delivered in February 2000. In early March acquisition programme personnel were scrabbling to respond to the questions. Within two months, three programmes contacted NAVSEA/Wallace at Dahlgren for advice on HSI. Programme leadership is now asking the right questions at programme reviews.

The conclusions from this experience are that change does begin at the top, and that leadership buy-in is vital. HSI specialists can assist, and get the higher levels of management concerned about human factors issues by providing quick, usable tools. To provide such tools the HSI specialists have to understand the acquisition and systems engineering process.

Topic 2

HFI/HSI Capability Maturity Models & Assessment Techniques

Workshop Discussion

Capability Maturity Models

Discussing the need for HSI process models for use in capability maturity evaluations, it was reported that the US Best Manufacturing Processes Programme had approached the US for an HSI template. In developing their approach, the UK had not yet identified or characterized different levels of capability maturity in the way that the Software Engineering Institute's CMM defines five levels of capability maturity. They may do this as they work through applications exercises. It was suggested that the major phases of the CMM process could be associated with the cycle of stages in improvement shown in the penultimate slide of the UK presentation: Initiating; Diagnosing; Establishing; Acting, and; Learning.

Discussing the differences between the HFI CMM and ISO 9000, the UK presenter, thought that the ISO 9000 style tended to be confrontational whereas the CMM is more cooperative. The aim was to support a deeper assessment of what is going on. In addition, ISO 9000 has no HFI reference model.

US DD-21 experience was that, with any plan, it is important to show where HF fits in the overall design team and what are the qualifications of the HF team. This linked to the observation of the UK under Topic 1 that trained HF specialists may not be available to do the necessary project management work. Availability of trained personnel in industry may also be a problem. Presumably there will be reconciliation at some time between the development of HSI aids intended for use by untrained HSI specialists and the development of CMM which emphasize the employment of trained personnel.

Assessment Techniques

Discussion of the problem of user requirements not being reflected in the specifications for new systems raised the question of using operators to evaluate designs. As one example, defence personnel from one navy went to another, saw consoles and decided they were what they wanted. However it turned out that the consoles were not suited to the way their navy operates. This illustrated the importance of the context in which equipment is operated. It was noted that operators evaluate designs on the basis of what they do now. However, usability is not effectiveness and opinions can change once personnel gain experience operating a system, or even a prototype, as had been shown in The Netherlands with bridge designs.

The following advice was recommended: end users are good at reacting to ‘visible’ designs (usually in the form of prototypes), however, they should not be brought in too early. One example is the development of the US SPAWAR Advanced Hooking Algorithm. Specifically, operators reported problems of having to precisely centre the display pointer over a symbol prior to hooking (selecting) it by means of a thumb switch on the console trackball. Scientists were able to see that a solution to the problem lay in different causes (i.e., develop software algorithms for computing which symbol is closest to the display pointer's current location) than those identified by end users (i.e., optimize the control-gain setting so that rapid movements of the trackball moved the display pointer large distances, while slow movements would allow precise positioning of the pointer). While there is literature on how to include users in usability issues and interface design the problem is larger – how to get the requirements right.

It was suggested that defining the subject matter expert (SME) is the root problem. HSI specialists have to work out the questions they want answered and who could provide the best answers. The end user organization has to decide who will be involved, but very often the SME nominees provided by the end user organization do not give much attention to the requirement. The example was cited of user reaction to a request for detailed design requirements as "we want a room for …[that]." A growing problem is that requirements are becoming less specific and more functional.

Charting procedures were recommended as a means of capturing the functional flow of a new system (see http://www.manningaffordability.com/Toolsite/Process/S3PDindx.htm). The focus is then on what the users are trying to accomplish. This will help to adjust the mindset of the end user. However, when task analyses are re-used from one project to another details of the analysis may not be appropriate. Task analyses must reflect changes in organization that come from changes in manning. US Naval Undersea Warfare Center produce an end-to-end model of a system using MicroSAINT to capture such information. This is very time consuming and costly but very useful.

One question which arose from the Bridge Cards briefing was how to get people to focus on human performance problems when human factors specialists do not have performance criteria to show that it is important? For example, the UK's HF handbook states that operators will not follow procedures once in a thousand times. How can HF specialists communicate the importance of human error given that kind of statistic? The answer it that it is not just probability that is important, but probability of occurrence multiplied by the consequence of a making such an error (sometimes referred to as expected value).

On the question of what value the Bridge Cards added compared to the US specification for Design Reviews (MIL-STD-1521 B: Technical reviews and audits for systems, equipments, and computer software) US delegates confirmed that they are not using that specification[4].

[4] After the workshop this was confirmed as a USAF standard, and its current status is unknown. The standard lists items to be covered at each major project review milestone. Early reviews cover HSI issues, whereas later reviews focus on HFE. Examples of issues from the standard are given in Annex D.

Topic 3

Tools and Technologies to Support HFI/HSI in the Acquisition Process

Manning Challenges for the Afloat Logistic & Sealift Capability Ship

Presenter,
Systems Engineer, Naval Human Factors,
Directorate of Maritime Ship Support,
National Defence Headquarters, Ottawa, CA

The Canadian Department of National Defence (DND) has initiated studies to procure an Afloat Logistic and Sealift Capability (ALSC) Ship. Current plans are to seek Preliminary Project Approval (PPA) next year, then move to construction. ALSC must satisfy a variety of mission requirements, some of which are new to the Canadian Navy. The ship is intended for:

- strategic sealift (transport vehicles and equipment, but not troops who will be flown),
- underway support to Canadian and allied task groups,
- in-theatre sea-based command, and
- joint/ combined support for forces ashore.

The manning concept must satisfy all requirements for operational missions, damage control, training, and helicopter operations. It is intended that the ship be manned by mixed-gender naval and support personnel, with the crew size and composition determined by the concept of deployment.

It is recognized that manning will be a major driver of operating costs, as well as many different parameters of ship design (see the author's brief to the TP-9 workshop in 1999). Consequently, manning has been a focus of the HSI effort to date, and efforts are further ahead than in the other domains. Current concepts are that manning will be of the order of 50% of an AOR crew, but that number will not be put in the Request for Proposals. Manning requirements include:

- first and second degrees of readiness,
- sea and harbour duty watches,
- daily departmental work,
- replenishment at Sea (RAS),
- stores and cargo handling, including embarking, Vertical Replenishment (VERTREP), barge or shore transfer,
- entering and leaving harbour,
- cleaning stations and ship's husbandry,
- maintenance of all systems,
- fire fighting and damage control,

- Nuclear, Biological and Chemical (NBC) defence readiness,
- launching and recovering ship's boats, and
- operating the ship when a prize or salvage crew is embarked on another vessel.

The ALSC project is about to let a manning study. They will then review the results of the study to identify where savings can be made.

The methodology adopted to study manning is based on the TP-9 HSI process developed in 1997. The basic premise that manning is determined by the allocation of functions to hardware, software, personnel on- or off-board (including combinations) early in the design phase. The functions to be allocated are to be derived from the analysis and decomposition of ship missions. Allocation of functions should primarily be based on costs; the total cost of human execution of a function includes the system life cycle cost of the trained operators, maintainers and supervisors who are required to perform the function.

Functions are then to be decomposed into tasks and the task analysis will be used to verify that representative personnel can perform all necessary tasks. The sum of personnel required to perform the tasks derived from the functions will provide the initial manning estimate. The estimate must then be adjusted to account for the watchstanding system, trade and rank progression, margins, etc. Finally, a simulation will be run to verify the results of the analysis. The study will not require the use of the Establishment Roster And SiMUlation System (ERASMUS), the DMSS-developed tool for estimating manning levels.

Potential cost trade-offs include alternative concepts for maintenance, ships husbandry, damage control, and crew organization, crew skills and job aids. For example, current practice results in ships where maintenance, not operations, is driving the manning levels; that seems wrong. In the area of damage control, DMSS are studying the US Damage Control by Automation and Reduced Manning (DCARM) project, which is performing a top-down functional analysis of damage control run by the Naval Research Laboratories. DCARM has yet to prove its ideas to the navy. Military crew, organised in the Divisional System, which groups individuals by Military Occupational Code, will be used for a first cut at the problem, but civilian crew may be considered. In the area of skill sets for advanced technologies such as Unmanned Aerial Vehicle (UAV) control we have to question whether we really need a fully trained pilot to control a UAV. In the area of labour saving, DMSS is following US studies on underway replenishment and how to reduce manning levels.

Topic 3

Tools and Technologies to Support HFI/HSI in the Acquisition Process

Early Human Factors Analysis Tool

This presentation was given by a representative of DERA, Centre for Human Sciences, UK.

Early application of Human Factors Integration (HFI) is crucial to ensuring issues are effectively covered in Requirements documents and the project approval process. Part of the MOD Corporate Research Programme in HFI research has been concerned with developing a method to assist in identifying the key human related issues that a procurement programme needs to consider. An important aim is to improve the design of future equipment by feeding forward lessons learned from both in-service equipment and about the process of procuring new equipment. Another aim is to produce design–independent techniques that can be used early in the procurement process.

The HFI research has produced a number of products to date. These include:

- Guide for Operational Requirements desk officers,
- Chief of Defence Procurement Instruction on HFI, CDPI/TECH/330, and
- Defence Procurement Management Guide DPMG/TECH/330.

A fourth product is known as the Early Human Factors Analysis (EHFA). EHFA is a process to help projects identify and assess human related risk. Human risks can include issues such as the ease of using or maintaining equipment, the number and type of people required, health and safety or training and maintenance costs. EHFA is intended to be simple and intuitive. It is closely associated with risk management and requirements engineering and is readily integrated with standard project management practice. Drawing from baseline assumptions and a high-level Target Audience Description (TAD), EHFA identifies HFI issues where there might be risk, and produces an HFI Issues Register and Assumptions Log. ‘Risk Registers’ are well understood in the MOD acquisition process. From the latter, risk mitigation strategies are developed and HFI considerations are incorporated into the business case for the proposed system.

EHFA is particularly powerful when projects are first starting up as it structures thinking about issues and risks, and provides input to project planning and risk management. As mentioned in an earlier briefing, the UK HFI programme has found that project staff are unlikely to include an HFI- trained specialist. Experience has shown that the technique is no substitute for a good analyst, but it is good for thinking about HFI problems. Further, end users should not assume that the EFHA process only needs to be performed once; rather, it requires an iterative cycle as the system or equipment design progresses. The application of EHFA led to the contracted development of an HFI Key Issues Tool (HFI-KIT). This is a windows-based set of linked databases that links HFI assumptions and issues and supports an approval process because each assumption must be approved.

HFI-KIT is organized around a flow of 'initial' concerns. Once identified, these concerns are rated as either not significant, or as something that must be expressed as a system requirement, or a requirement in the development process, or something that requires management action. To date, HFI-KIT has been applied to the future surface combatant, TRACER, future attack submarine, airborne standoff radar and future infantry system technology programmes. Feedback on the tools from the above applications has been that it is useful in generating themes that would otherwise have gone unnoticed and would not be picked up by conventional HF analysis.

Case studies show it is important to apply HFI early in a project, and that EHFA is a core activity in developing the system concept. Use of the software tool made the DERA developers think again about the original guidance documents and recognize the need to restructure them. As well, HFI-KIT needs to accommodate different ways of working. An annex to the report on the tool suggested Prompts & Issues Sheets would be a useful enhancement.

Topic 3

Tools and Technologies to Support HFI/HSI in the Acquisition Process

Intelligent Computer-aided Design System for Ships' Operating Spaces (HFE/ICADD): Re-hosting from SGI Workstation to a Desktop PC Environment

Presenter,
Options Inc., Guelph, Ontario,

Presenter,
Protogon Inc., Ottawa, Ontario, CA

HFE/ICADD, which was briefed to TTCP HUM TP-9 during the 1996 meeting (see TTCP/SGU/96/11), was intended to assist the DMSS human factors specialists with the review of ship spaces, and the management of ship space reviews. The functions of a computer-based system for supporting human factors engineering in the ship design and review process were established in the following areas:

- Integrate contractors into the design process.
- Provide for the generation and use of HF requirement checklists.
- Permit rapid, and eventually automatic, dimension checking.
- Facilitate incorporation of task data involved in use of shipboard spaces.
- Fit with existing or emerging software products supporting HF in the design cycle.
- Provide for key tasks such as preparing drawings for review, choosing and checking items on a drawing in terms of compliance with a requirements checklist and task requirements, record decisions and reasons, and build and edit checklists.

HFE-ICADD system was designed as a hardware and software solution integrating custom software with Commercial Off-The-Shelf (COTS) software through custom developed software running on a Silicon Graphics computer. Over the lifetime of HFE-ICADD several changes occurred in the Canadian Department of National Defence (DND) that limited the use made of the tool. First, the number of personnel available to use HFE-ICADD in-house was reduced though downsizing. Second, all DND life-cycle management directorates adopted a standard office space 'cubicle', which precludes the effective use of the scanners and plotters. At the same time most life-cycle support activities associated with human factors issues have retained the use of paper drawings. The Information Technology (IT) environment in DND was standardized on personal computers running COTS software. The current configuration of HFE-ICADD does not meet that requirement and it does not receive in-house support. Due to these changes little use has been made of HFE-ICADD. This has the unfortunate consequence of limiting the development of a sufficient body of examples for the case-based reasoning functions to have high utility.

Recently, under a business change initiative in DND, templates have been developed for the preparation of Statements of Requirements that require human factors issues to be addressed. This business change initiative is associated with the adoption by project management offices of software tools for the development and tracking of requirements. Some 30 projects are now using the Dynamic Object-Oriented Requirements System (DOORS) requirements tracking software, as will the ALSC project reported by Menard (above). Thus there is a potential link between the activities of desk officers involved in requirements development and HSI specialists involved in design review, and HFE-ICADD should be compatible with the use of requirements management software.

In response to these developments, DCIEM recently contracted two studies of the feasibility of implementing HFE-ICADD within the current DND IT environment and integrating the human factors requirements management role into the core project requirements work stream as set down by the Department's Directorate of Business Change Management. With the goal of using as many commercially available products as possible, the functionality of a wide range of COTS produces was reviewed for supporting HFE-ICADD functions (see Table 1).

Table 1: HFE-ICADD functions performed by COTS software

HFE-ICADD FUNCTION	COTS SOFTWARE
Checklist	DOORS RM Tool
Drawing	CADD and Reline tools
Manikin	Mannequin Pro? SAFEWORK (2001)
Task Information	Various databases
Deficiency Report Generation	DOORS RM Tool
Historical Cases	None
Automatic Constraint Checker	None

The tasks originally used in the HFE-ICADD training package were used to verify the functionality of a COTS-based solution. It was concluded that much of the functionality of HFE-ICADD was available through COTS packages:

- Import and manage requirements linked to sources or other requirements in DOORS.
- Review and redline drawings using one of many Microstation compatible products.
- Create, complete, and manage checklists in DOORS.
- Use Mannequin Pro used for visualization.
- Insert any graphics files created into a DOORS checklist file.
- Create Deficiency Reports in DOORS.

At the same time problems of software integration were studied and trial assemblies of software packages were run to explore integration in a desktop environment. The architecture of a possible HFE-ICADD system was developed, with the 'Intelligent' aspects remaining as special-purpose software. The opportunity was also taken to address some of the user concerns identified in trials of the original HFE-ICADD.

With other large procurement projects using DOORS for requirements management, there is an opportunity to use that software in the way outlined as a replacement for the original HFE-ICADD. At least two projects, one air, one land, will be using DOORS in a similar fashion to HFE-ICADD.

Topic 3

Tools and Technologies to Support HFI/HSI in the Acquisition Process

Update on HSI Standards, Models & Tools for US Navy Ship Acquisitions

Presenter,
Basic Commerce and Industries, Inc.,
Colorado Springs, Colorado, US

As reported to previous workshops, a number of efforts are underway within the US Navy to implement Human System Engineering Models, Tools, Methods, and Standards from a designer's and an evaluator's perspective. Relevant programmes include:

- *ONR/SC-21 S&T Manning Affordability Initiative* (MAI), which includes Thrust 3, the Human Centered Design Environment (HCDE),
- *Ship Manpower Analysis and Requirements Tool* (SMART), and
- *Ship System HSI for Affordability and Performance Engineering* (SHIPSHAPE) efforts.

As reported at the US Office of Naval Research web site http://www.manningaffordability.com the Manning Affordability initiative has three complementary thrusts to manning affordability:

- job design,
- watchstation design, and
- HF performance models and metrics.

To facilitate these thrusts a number of developments are ongoing in each thrust area, as follows.

The Stand Alone Search Agent (SALSA) includes human factors guidelines from the US Federal Aviation Administration (FAA), MIL-STD-1472, and Situation Awareness guidelines, as well as software for capturing and retrieving case studies. It is undergoing usability testing and additional guidelines are being added. It will be linked to the Manning Affordability web site and folded into the Human Centered Design Environment/ Human Centered Design Advisor.

The Human-Centered Design Environment (HCDE) treats the human as an integral part of the system, focussing specifically on the development of human engineering (HE) tools, and the integration of hardware, software, human engineering disciplines into a total system engineering process. HCDE is a mix of COTS software tools that are linked to a common design repository by the Trident Systems Incorporated (TSI) Interchange^{tm} Tool; consult http://www.manningaffordability.com/Toolsite/Tools/Detdesci/dindtsii.htm for additional information. In addition, work by the HCDE team is aimed at including a human-centered engineering process within extant systems engineering process standards. These include IEEE 1220, ISO 15288 LCM S Life Cycle Processes and, the International Council on Systems Engineering (INCOSE) Systems Engineering Handbook. The project is also beginning to exploit multi-modal technology to develop the design environment.

The Team Integrated Design Environment (TIDE) being developed by Aptima is aimed at designing work organizations through multi-objective algorithms for function allocation. The results are evaluated through simulation. (PowerPoint presentations on TIDE were distributed to members on 19 May 1999). TIDE is due for evaluation in July 00.

The ORGNET (methodology) /PRO (toolset for redesigning organizations) is based on the commercial iGEN^tm tool for building cognitive agents and is a model of real time team cognitive activity. The aim is to aid in designing teams using task criteria based on simulation of manual, cognitive and automated processes. Resulting models can be used for HSI. Developers are working on performance metrics and task timeline visualization.

The Multi-Modal Watch Station (MMWS) instantiates a task centred approach to design for watch-standing. The watch station also includes active monitoring and adjusting of workload in real time across a warfighter team. It is being used in the Integrated Command Environment (ICE) laboratory, described in more detail below.

SHIPSHAPE is intended to standardize and formalize the application of HSI in ship/ system acquisition. The aim is to support the HSI analyst by providing, at one location, data, methods, tools, guidelines, and aids

Systems Engineering Analysis Integration Tool (SEAIT) is being produced by MicroAnalysis and Design Inc, the developers of MicroSAINT and the Integrated Performance Modeling Environment (IPME). SEAIT is an integrated performance evaluation, workload assessment and decision support tool for assessing HSI aspects of naval and commercial ship designs. It is based on simulation model of crew, equipment and functions. Jobs are described by skill requirements. It includes a software module for numerical analysis to identify skill requirements. Currently the developers are entering a USN database.

The Ship Manpower Analysis and Requirements Tool (SMART), a 6.3 (advanced development) effort sponsored by the US Office of Naval Research, is intended to provide the Navy manpower analysis center (NAVMAC) with a design process and toolset that allows them to assess ship manpower requirements and workload demands before any building takes place. It includes scalable architecture that permits various warfighting roles, multiple missions, ship organizations and team structures to be examined.

The focus of the Human Scriptable Animation (HSA) development is to develop a generic standard language for modelling and simulation tools to allow Task Network Models to drive CAD manikins such as Jack or SAFEWORK. Phase 1 should be complete this summer.

The Integrated Command Environment (ICE) has been quite successful to date and is funded for the next step. Currently the ICE team is doing performance tracking on an AEGIS cruiser then testing the same activities in ICE using the MMWS (above). The DD 21 Program Manager wants the commander to have ‘instant situational awareness’ when he enters ICE, and that requirement will be the focus of the next stage.

Topic 3

Tools and Technologies to Support HFI/HSI in the Acquisition Process

The Mission Manpower Model - Recent Developments

Presenter,
Maritime Platform Division, DSTO, AS

The Maritime Platforms Division (MPD) of DSTO is investigating two approaches to crew complement modelling. One is based on MicroSAINT, a discrete event stepped simulation of task networks. The other is based on a scheduling model originally called the Mission Manpower Model (MMM), demonstrated to TP-9 in 1998.

MMM is a software design tool, which tests ship missions against a complement, system or equipment fit and resource pool. Simulating each mission identifies deficiencies and overloading of personnel, systems or resources. The simulations produce detailed mission task schedule graphs, usage charts and error reports. Typical uses of the MMM include:

- reducing complement requirements through automation,
- determining optimal system/equipment fits,
- determining maximum resource loads,
- sensitivity analysis of ship design parameters, and
- determining training requirements for new designs and/or equipment.

As explained in the Australian update on their HSI programme (above), the MMM software was originally developed by Mercadier Pty. Ltd. (MPD) for an offshore patrol combatant of the 1990s. The MMM has recently been ported to a Windows environment, with many enhancements including:

- improved user interface and operating environment,
- access database, and
- integration with a MapInfo Geographic Information System.

The new version of the software, which was delivered only days before the workshop, is called the Ship Resource Simulation Model SRSM. The new software responds to users needs to model ship’s complements from a general point of view.

SRSM is based on a database of an operational profile, including platform missions, activities, and tasks. A platform database contains information on ship resources, ship systems and crewing levels, and can draw from platform models such as vulnerability, structural management, signature models, developed by MPD. Each mission has a list of serials, states, environments, activities, and primary tasks. Each task contains a list of skills, called enabling tasks that permit people to perform it. Each primary task can have crew assigned to it.

In the simulation model, structures are built up using top-level data. The model will generate manning requirements if it is run without defining a complement. It has no capability to recommend changes in the allocation of function, for example to automate a specific system. The model can check if the platform can carry out all designated activities at once. The model still has some problems, but is available for evaluation by TP-9.

Topic 3

Tools and Technologies to Support HFI/HSI in the Acquisition Process

Workshop Discussion

Potential users were interested in Canada's experience with DOORS. Limited experience to date suggests there are definitely a few challenges in using DOORS for HSI applications. Specifically, it was noted that the DOORS structure did not transfer in an obvious way to the flows of information being generated by some projects. The initial conversion of legacy material is also a problem. DND is trying to implement DOORS templates in the Acquisition Desktop, which will be used by desk officers developing requirements for new systems and equipment.

A US tool developer pointed out that their SEAIT tool does a lot of the same things as the SRSM simulation model. Workshop participants agreed that there is no shortage of tools for estimating manning. The important question is how useful are they? That question is being addressed by work undertaken under the TP-9 Task Proposal Summary plan for 'Tools for optimising naval platform manning and manpower requirements.'

Techniques for estimating manning and manpower requirements were also of concern. For example the Canadian ALSC project will use the Divisional System for organizing manpower, because, for this ship, they want to use the existing Military Occupation Codes (MOC) structure. US SC-21 experiences suggest that this will likely be problematic. The most cost-effective re-allocation of manpower is at the bottom of the personnel pyramid, so that will drive the allocation and change the MOC structure. (Some participants disagreed with the Canadian proposal to base the function allocations on costs alone; they argued that performance has to be taken into account as well)[5]. The ALSC will use existing MOCs and a military crew for a first estimate of the manning, but they may switch to examining a commercial crew. US experience reinforces the need to include recruiting and training costs in manning costs, especially if novel crewing options are being considered.

There was discussion of two approaches to manpower modelling and simulation: scheduling models versus the task network model (TNM) approach, both of which are being examined by Australia's DSTO MPD. One concern was whether the large amount of effort required to develop a TNM model is justified early in the design process, when the necessary details are not available. Current models seem to be very specific about the data they need, so it is not easy to re-use the data from one model to another. It would be desirable to adapt the tools to allow for

[5] US DoD 5000.2M 'Defense acquisition management documentation and reports' states that trade-off analyses "describe equal-cost or equal-capability packages."

data exchange. It was suggested that an entity-relationship diagram for the different models would show what data are common and what are unique to each.

There was general agreement that many of the models require a large amount of data to be input, which has been a disincentive to using them. The UK, which is performing a comparative evaluation of available models, thought that it would be useful to gain experience using these tools on an actual project. However, contractors have already expressed reluctance to use two tools on the same project because of the large amounts of data that must be entered.

Differences between models have arisen in part because the clients have asked different questions. Some clients are interested in task timeline analyses while others want time on task; consequently, the specific manpower and workload requirements the models are trying to measure often determines both data input and simulation output. Because of these differences some models have structural limitations, for example being unable to specify that an activity starts at a specific time. The RAN wants to use SRSM for crewing for specific purposes, for example to man a ship for a specific mission. This poses the question that if you take people off who are not associated with that mission, what other capability is lost?

Concern was expressed about the stability of the predictions made by some models. Some manning solutions are highly unstable. Given the experience reported by Australia (above) that maintenance requirements for one of their platforms were underestimated, leading to an increase in manning, what sort of perturbation can manning models deal with? Could you run the SRSM with maintenance problems and show instability?

The topic of Early Human Factors Analysis again raised the role of the TAD. The UK had reported that the TAD was central to their approach to EHFA. Experience was that it requires discipline to carry out properly and reliably and it can be misleading at fine levels of detail. The UK regard preparing the TAD as a facilitation process, identifying who will be available to man a system in 2010, for example, but admit that they have not used it enough. The most useful aspect is the description of the users' physical capabilities and the effectiveness of the TAD may depend on the scale of the project.

OVERALL DISCUSSION

The following general themes emerged from the workshop.

HSI Domains

There are differences between services and nations. These differences are probably not significant but are an adaptation to specific needs. In the context of this Panel, if any additional domain is to be added to HSI it should be in habitability and quality of life. (US NAVSEA has put in a comment on the DoD Instruction 5000 series of documents that habitability/ quality of life should be a major concern of HSI).

Manning will continue as a major driver of through-life costs and optimum manning is the current major challenge.

The MPTS domains drive system life cycle costs, whereas HFE is the key to making the MPTS domains work.

Policy

HSI practitioners need an overall policy (think globally) and tools and processes to implement it on specific projects (act locally). Any HSI policy must be linked to, and concurrent with, initiatives for organizational and cultural change.

HSI Expertise

Trained HF specialists may not be available to perform the necessary project management work. HSI tools and techniques may need to be adapted to non-specialist users.

The availability of trained personnel in industry may also be limited.

Tools and Techniques

Some workshop participants reported that they have never used the TAD (USN); some use it with caution (RN); and some see it as having a lot of potential if written in a way that helps system designers. The technique needs more development and users need a guide on how to write one properly.

Task analysis must reflect changes in organization that come from changes in manning. Thus, when task analyses are re-used from one project to another there can be problems in the appropriateness of the analysis.

User requirements specifications and user requirements for functionality can differ markedly. The two have to be reconciled. At present this is achieved through frequent reviews by users in an evolutionary approach to development. The selection of user representatives requires some skill and preparation.

A functional decomposition can help the dialogue with the users and a top-down functional analysis can make a major contribution to HSI.

Increasing value is being obtained from TNM for HSI, not just for HFE. However such analyses may not be cost effective for studying manning issues early in the development cycle.

There is no shortage of tools for manning, however their relative merits are still unclear. Should the Panel just select the best and go ahead, or will there be value added in further development?

Despite the conclusion from the previous workshop on the need to measure costs, there was little discussion of cost models as HSI tools. The COMET Cost Analysis tool was mentioned as one of the tools in the US Manning Affordability initiative, but no others were discussed.

Some nations are developing software that replicates the functions of software already developed in other nations. For example: the US has developed SEAIT which has similar functions to the Australian MMM/ SRSM; the US has developed a case study tool in their Minimum Collateral Damage Weapon (MCDW) and Canada had previously incorporated case-based reasoning and a taxonomy of ship design problem areas in HFE-ICADD. This raises the question of the most effective form of collaboration on such tools. The IPME software seems to be the only genuine case of TTCP collaborative development of HSI tools, with the UK and CA funding development of software by a US company. Otherwise most collaboration appears to be in the exchange of ideas.

GLOSSARY AND ABBREVIATIONS

ADM - Admiral

ALSC - Afloat Logistic and Sealift Capability ship – a proposed Canadian acquisition project

AMS - UK's Acquisition Management System

AOR - Auxiliary Oiler/Replenisher

C2 - Command and Control

CAD - Computer Aided Design

CHS - Centre for Human Sciences, DERA, UK

CMM - Capability Maturity Model - a method for assessing the capability of an organization to develop reliable, cost-effective products

COTS - Commercial, Off-the-Shelf hardware and software items

CREW2 - the Complement Regimes Evaluated for Warships 2 – a UK manpower modelling software programme

DERA - Defence Evaluation and Research Agency, UK

DMSS - Directorate of Maritime Ship Support in the Canadian Forces

DND - Department of National Defence, Canada

DoD - Department of Defense, USA

DOORS - Dynamic Object-Oriented Requirements System – commercially available requirements tracking software

DRDC - Defence Research and Development Canada

DSTO - Defence Science & Technology Organisation, Australia

EHFA - Early Human Factors Analysis – an approach developed by DERA, UK, to initiate human systems integration activities early in a project

ERASMUS - Establishment Roster And SiMUlation System—a software tool for estimating manning levels developed by DMSS, Canada

FEG - Force Element Group – an organizational unit

HCDE - Human Centered Design Environment – a US Manning Affordability initiative

HEART - Human Engineering Analysis and Requirements Tool – a Canadian human factors engineering tool-set

HF - Human Factors

HFE - Human Factors Engineering

HFE-ICADD - Human Factors Engineering Intelligent Computer-Aided Design and Drafting system

HFI - Human Factors Integration - the process of integrating human factors issues with the system design

HFI-KIT - Human Factors Integration – Key Issues Tool Kit – a software-based tool developed by DERA, UK

HMI - Human-Machine Interface

HSA - Human Scriptable Animation - a generic standard language to allow Task Network Models to drive CAD manikins such as Jack or SAFEWORK

IEEE - Institute of Electrical and Electronic Engineers

HSI - Human-Systems Integration - the process of integrating human factors issues with system design and development

HUM - Human Resources and Performance Group of TTCP

ICE - Integrated Command Environment – a US NAVSEA project to investigate and demonstrate advanced command space layouts and technology

ILS - Integrated Logistic Support

INCOSE - International Council on Systems Engineering

IPME - Integrated Performance Modeling Environment – a task network modelling simulation language that includes performance shaping factors and an information processing model of operator workload

IPTs - Integrated Product Team – an initiative to establish more collaborative relationships between government and industry in an acquisition project

ISO - International Standards Organisation

ITT - Invitation To Tender

Jack - a commercially available software tool for generating 3-dimensional representations of users in a CAD environment

KCAs - Key Collaborative Areas – areas of collaborative research within a TTCP panel

M&S - Modelling and Simulation

MA&S - Material Acquisition and Support – an acquisition management programme

MAI - Manning Affordability Initiative - US

MANPRINT - MANpower and Personnel Integration programme of the US Army

MicroSAINT - a micro-computer based version of the US Air Force Systems Analysis of Integrated Networks of Tasks (SAINT); it provides a modelling and simulation language for representing operator activities by networks of tasks. MicroSAINT is maintained and distributed by Micro Analysis and Design, Boulder, Colorado, USA

MMM - Mission Manpower Model – developed by Mercadier Pt. for DSTO, Australia

MMWS - Multi-Model Watch Station – a US Manning Affordability initiative

MOC - Military Occupational Classification

MOD - Ministry Of Defence, UK

MOE - Measure of Effectiveness – a measurement related to the effectiveness of a system

MOP - Measure of Performance – a measurement of performance of a system or system component, which may or may not be relevant to system effectiveness

MPD - Maritime Platforms Division – a branch of DSTO, Australia

MPT - Manpower, Personnel and Training – three domains of human systems integration

NAVSEA - US Naval Sea Systems Command

NBCD - Nuclear, Biological and Chemical Defence

OAC - Operational Analysis and Costing

OR - Operational Requirements

PCH - Policy Clearing House – a US manning affordability initiative to exchange information on policy, statutes, procedures and culture that influence manning levels

PEO - Program Executive Office

RAN - Royal Australian Navy

RBA – Revolution in Business Affairs

RMA - Revolution in Military Affairs

RN - Royal Navy

SAFEWORK - a commercially available software tool for generating 3-dimensional representations of users in a CAD environment

SBA - Simulation Based Acquisition

SC-21 - 21st Century Surface Combatant - a ship design programme for the US Navy

SDR - Strategic Defence Review

SEAIT - Systems Engineering Analysis Integration Tool - an integrated performance evaluation, workload assessment and decision support tool for assessing HSI aspects of naval and commercial ship designs produced by the developers of MicroSAINT

SEI - Software Engineering Institute - a US federally funded research and development center owned and operated by Carnegie Mellon University, Pittsburgh, Pennsylvania

SHIPSHAPE - Ship System HSI for Affordability and Performance Engineering – a US Manning Affordability initiative

SMART - Ship Manpower Analysis and Requirements Tool – a 6.3 (advanced development) project sponsored by the US Office of Naval Research

SMART - Simulation and Modelling for Acquisition, Rehearsal and Training – a Canadian set of software tools supporting design trade-off analyses, mission rehearsal and training simulation

Smart Procurement – an initiative within the UK Ministry of Defence aimed at better, faster, and cheaper methods of procurement than current programmes

SME - Subject Matter Expert

SOLE - Systems Operator Loading Evaluation – a Canadian set of software tools for conducting mission, function, and task analysis and task-network workload simulation

SOLE-IPME - the latest version of SOLE that uses the Integrated Performance Modeling Environment to host the task network workload simulation

SOR - Statement of Operational Requirement

SPAWAR - US Space and Naval Warfare Systems Command

SPICE - Software Improvement and Capability dEtermination model developed by the ISO for assessing an organizations' capability to produce reliable, cost-effective software

SRSM - Ship Resource Simulation Model – the new name for the Australian MMM software model

SSC-SD – SPAWAR Systems Center San Diego – a US Navy R&D laboratory under cognizance of the Space and Naval Warfare Systems Command

TAD - Target Audience Description – a term for the description of personnel capabilities provided as part of an HFI/ HSI programme

TAG - Technology Advisory Group –a group of government and industry human factors specialists in the USA

TNM - Task Network Modelling – typically conducted using MicroSAINT or IPME

TOM - Technology for Optimized Manning – a UK/ US collaborative project to identify technology that will contribute to reduced manning for surface combatants entering service between 2010 and 2020

UAV - Unmanned Aerial Vehicle

USN - US Navy

ANNEX A

Key Points From the Workshop on "Design and Evaluation of Principal Operating Areas in Warships" (May 1998)

The workshop was organized around three topics:

Topic 1: Design drivers for future naval principal operating areas
Topic 2: Current state of research, tools and techniques
Topic 3: Case studies and lessons learned

Key points from the discussions were clustered into the topics of:

- Vision
- Technology Drivers
- Personnel Drivers
- The Acquisition Process

<u>Vision</u>

- Similar operating space concepts are being examined by different nations. Concepts for the US ICE and UK Command Space 2000 are similar.

- To what extent should we let technology drive the solution? Technology is no longer the limiting factor, but it allows many more degrees of freedom in design.

- We are able to consider distributed vs. centralized, fixed vs. mobile and team vs. individuals as design solutions for C2. There are lots of ideas, but there is no clear direction. We need an agreed view on what we want to achieve, and a common set of guidelines. The client needs a vision. Technology allows us to consider revolutionary changes in information handling equivalent to the change from sail to steam, but there is resistance to changing concepts.

- These choices produce the dilemma of aiming for reduced manning but using technology that implies more roles and more information to be handled.

- We need a more integrated view of C2 platform management - a total systems view including storage, supply, logistics, etc.

- We must be clear what are the HFI/ HSI objectives for naval systems. What do we want to do with the system? HSI needs clear design criteria. Is the goal of HSI to reduce costs?

Technology Drivers

- Most technologies are applicable to current as well as future platforms.

- The proliferation of possible interaction modalities is outstripping our capability to evaluate and identify how they should be applied, for example, our ability to determine the best mix of technologies for a particular application such as the choice between 2D vs. 3D displays. As another example, what are tangible applications of speech technology?

- Flawed assumptions have been made about the potential benefits of some new technologies. We need to look at the worst case when evaluating new technology, e.g., speech recognition in an NBCD suit.

- We should be considering the potential use of software agents.

- Mobile computers offer the opportunity to move away from fixed console locations.

  a. How do we make best use of this?
  b. What is the potential for systems that adapt to the skill level of the user?
  c. How do we model team dynamics and interaction?
  d. What are the benefits and penalties of large-screen shared displays?

Personnel Drivers

- MPT issues must be considered early, in the concept phase.

- Lead times for getting the MPT right may be as long, or longer, than getting the equipment.

- Branch structure may be a major driver of MPT solutions.

- Solutions must reflect how the system will actually be used.

- Reduced manning offers the ability to make improvements to habitability. Social expectations, working and living conditions affect retention. Where is the boundary with HSI? Psychological, physiological and sociological limitations may be design determinants.

The Acquisition Process

- If undertaken sufficiently early even a small HSI effort can have major benefits. Short, well-focused HSI studies can give good value.

- There is need for new analysis techniques to tackle technological changes. We have to answer questions such as 'Are small ships cheaper?'

- There is no shortage of tools for dealing with the ergonomics aspects. Procedures are needed for evaluating radically new design concepts and ship borne technology demonstrators.

- How do we exploit the potential to be much more flexible in the allocation of functions?

- How can we make best use of new technology, such as synthetic environments to allow early visualisation of design concepts?

  a. Can we construct a virtual ship model of people?
  b. Are simulated design environment (e.g., 3D CAD) representations adequate for evaluation?
  c. Will simple plan and elevation views suffice?
  d. When and where are physical mockups needed?
  e. How can we integrate HF issues into simulation-based design tools?
  f. What is the relationship between Human Factors and the rest of Systems Engineering?
  g. We need better knowledge of how people design ships.

- What are the HSI/ HFI measures of success for naval systems?

- We need a common approach to calculating manpower costs.

ANNEX B

Conclusions From the TP-9 Workshop on Optimized Manning (May 1999)

Workshop papers were categorized according to their scope for dealing with MPT and HFI issues (individuals, teams, platforms, and fleet applications) as shown in the following tables.

Scope of HSI	Paper No.	Models and Tools	Author
Individuals	2.4	Cognitive work analysis for the design and analysis of military platforms	Presenter, DSTO, AS
	3.1	What are the performance differences between USN and RN novices and experts?	Presenter, NUWC, Newport, US
Teams	2.1	Function analysis in the future command study	Presenter, RNLN, NEL
	2.3	Reduced manning and design analysis of CIC concepts developed for DD-21	Presenters, DCIEM, CA
	2.5	Lessons learned from the M-frigate assessment	Presenter, TNO, NEL
	2.6	Using network modeling to investigate manning levels and HFI in the NORAD command system	Presenters, DCIEM, CA
	3.2	Human factors in the future command study	Presenter, TNO, NEL
Platforms	1.1	A comparison of design drivers used by naval architects with those used by human factors specialists	Presenter, DMSS, CA
	1.3	Manning approaches for the Netherlands Navy	Presenter, RNLN, NEL
	1.6	Science and technology: UK/ US manning vision	RN Liaison Officer, UK Embassy, Washington
	2.2	CREW2: a tool to validate platform complements	MOD (PE) UK
	3.3	Reduced manning: engineering an organizational perspective	RN, Directorate of Naval Manning, UK
	3.4	DD-21 optimized manning: cultural challenges	Presenter, NAVSEA, Arlington, VA, US
	3.5	Development of a complement visualization tool	DERA/CHS, UK
	3.6	Status of the human centered design environment and manpower models for the US Navy	Presenter, BCI Inc., W. Nugent, SSC, SD, US

Fleet	1.2	Investigating demographic and technical requirements for the RAN using scenario planning techniques	Presenter, DSTO, AS
	1.4	Future trends in RN complementing policy and practice	RN, Directorate of Naval Manning, UK
	1.5	Sailor 21: a research vision to attract, retain and utilize the 21st century sailor	Presenter, NPRDC Washington DC, US

The workshop papers were also categorized according to the Key Technology Areas of TP-9 that they supported, as shown in the following table.

Scope of HSI	KCA-1: New technology for command centres	KCA-2: Acquisition process and HSI	KCA-3: Optimized manning
Individual			Papers 2.1, 3.1
Teams	Paper 3.2	Papers 2.1, 2.3	
Platforms	Paper 1.6	Papers 1.1, 3.6	Papers 1.3, 1.6, 2.2, 2.6, 3.3, 3.4, 3.5, 3.6
Fleet			Papers 1.2, 1.4, 1.5

Finally, the papers were categorized and the technique or tool that they used was rated for maturity and confidence in their products.

Tool/ Technique	Application	Maturity	Confidence
CREW2	Platform	4	4
CREW Visualization Tool	Platform	6	6
SMART (Ship Manpower Analysis and Requirements Tool - US)	Platform	1	1
LOCATE (CA)	Teams	6	6
PRO (model of ship's readiness - US)	Platform	6	6
HCDE (Human Centered Design Environment - US)	Platform	4	3
Function/ Information Integration Model	Teams	2	3
Task Network Modelling	Teams	6	4

Tool/ Technique	Application	Maturity	Confidence
Scenario Planning Technique	Fleet	6	4
Work Domain Analysis (part of Vincente's Cognitive Work Analysis)	Individual	2	4
WDAW	Individual	6	6
Klein's Cognitive Task Analysis	Individual	5	5
Centreline	Individual	6	6

Discussing the tools and techniques available to optimize manning, it was agreed that it is very useful to have tools such as CREW, SMART and the Mercator Mission Manpower Model (MMM) tool available. However, in future we need to know their capabilities and data structure to be able to re-use the data from one tool to another.

There were two overall conclusions of the workshop. First, that manning is a major driver of through-life costs and that lean manning is the current major challenge. Second, that the acquisition process (KCA-2) and new command system technologies (KCA-1) will facilitate lean manning and will require focussed effort in the future.

ANNEX C

1. UK HFI PROCESS

- Establish HFI focus as part of the IPT
- Review operational scenario
- Update/ conduct Early Human Factors Analysis
- Seek advice from HF centres of excellence
- Formulate HFI strategy
- Identify HFI resources and funds
- Produce HFI plan
- Obtain Task Analysis Data
- Review and Verify Manpower and Personnel Requirements
- Develop Target Audience Description
- Develop Training Needs Analysis
- Identify Need For Performance Trials and User Access
- Identify Need For HF Style Guide
- Produce HFI Section For ITT
- Develop HFI Acceptance Criteria

2. UK HFI PLAN

- Audit trail for design decisions
- Addresses dependencies
- Defines inputs/outputs
- Sequence of HF activities
- Importance of HF activities
- Timing and scope deliverables
- Production and timing of HF Requirements
- HF Specifications
- Lists Assumptions (i.e. timely access to SMEs, timescales, priorities, access to data)
- HF objectives and tasks
- HF Team organization
- Work breakdown and scheduling
- Configuration control

ANNEX D

Material in US MIL-STD-1521B Relating to HSI Issues

System Requirements Review (SSR) (sic)

"Such reviews …. normally will be conducted after the accomplishment of functional analysis and preliminary requirements allocation (to operational/ maintenance/ training Hardware Configuration Items (HWCIs), Computer Software Configuration Items (CSCIs), facility configuration items, manufacturing considerations, personnel and human factors) …"

"Items to be Reviewed [include] … System Safety; Human Factors Analysis; … Life Cycle Cost Analysis; … Manpower Requirements/ Personnel Analysis …."

System Design Review (SDR)

"The review encompasses the total system requirements, i.e., operations/ maintenance/ test/ training, hardware, computer software, facilities, personnel, preliminary logistic support considerations."

"Items to be Reviewed [include] … System Safety; Human Factors Analysis; … Life Cycle Cost/ Design to Cost Goals; … Environmental Conditions, Training and Training Support, …" [and the] Results of significant trade studies, for example: sensitivity of selected mission requirements versus realistic performance parameters and cost estimates …. Functional allocation between hardware, software, firmware and personnel/ procedures"

Preliminary Design Review (PDR)

"… shall be held after the Hardware Development Specification(s), the Software Top Level Design Documents (STLDD) … and preliminary versions of the Computer System Operator's Manual (CSOM), Software User's Manual (SUM), … are available."

"Items to be Reviewed [include] ….. Equipment layout drawings and preliminary drawings … Mock-ups, models, breadboards, or prototype hardware when appropriate … Human Engineering and Biomedical Engineering considerations (including life support and Crew Station Requirements)"

40.6 Design Maintainability

40.7 Human Factors

"40.7.1 The contractor shall present evidence that substantiates the functional allocation decisions. The Review shall cover all operational and maintenance functions of the configuration item. In particular, ensure that the approach to be followed emphasizes the functional integrity of the man with the machine to accomplish a system operation."

"40.7.1 Review design data, design descriptions and drawings on system operations, equipments, and facilities to insure that human performance specifications of the hardware development and Software Requirements Specifications are met. Examples of the types of design information to be reviewed are:

- operating modes for each display station, and for each mode, the function performed, the displays and controls used, etc.,
- the exact format and content of each display, including data locations, spaces, abbreviations, the number of digits, all special symbols (Pictographic), alert mechanisms (e.g., flashing rates), etc.,
- the control and data entry devices and formats including keyboards, special function keys, cursor control, etc.,
- the format of all operator inputs, together with provisions for error detection and correction, and
- all status, error, and data printouts - including formats, headings, data units, abbreviations, spacings, columns, etc."

"These should be presented in sufficient detail to allow contracting agency personnel to judge adequacy from a human usability standpoint, and design personnel to know what is required, and test personnel to prepare tests.

- Make recommendations to update the System/ Segment , or Software Requirements Specification and Interface Requirements Specification(s) in cases where requirements for human performance need to be more detailed.

- Review man/machine functions to insure that man's capabilities are utilized and that his limitations are not exceeded."

40.8 <u>System Safety</u>

50. <u>Critical Design Review</u>

50.7 <u>Human Factors</u>

"50.7.1 Review detailed design presented on drawings, schematics, mockups, or actual hardware to determine that it meets human performance requirements of the HWCI Development Specification and Software Requirements Specification(s), and accepted human engineering practices."

"50.7.2 Demonstrate by checklist or other formal means the adequacy of design for human performance."

"50.7.3 Review each facet of design for man/ machine compatibility. Review time/ cost/ effectiveness considerations and forced trade-offs of human engineering design."

"50.7.4 Evaluate the following human engineering/ biomedical design factors:

- operator controls,
- operator displays,
- maintenance features,
- anthropometry,
- safety features and emergency equipment,
- work space layout,
- internal environmental conditions (noise, lighting, ventilation, etc.),
- training equipment, and
- personnel accommodations."